

# Properties of Fibre Bragg Grating in Optical Fibre Systems

Sabirin Ikhsan, Hairurizal Muhamad Supian and Rosly Abdul Rahman  
Fibre Optics & Photonics Research Laboratory  
Department of Physics, Faculty of Science  
Universiti Teknologi Malaysia  
81310 Skudai, Johor, Malaysia  
Tel: 07-5576160 Ext:4110/4079  
Fax: 07-5566162  
e-mail : [rar@dfiz2.fs.utm.my](mailto:rar@dfiz2.fs.utm.my)

**Abstract-** A fibre Bragg grating is a short section of optical fibre in which the core refractive index has a periodic modulation. They are produced by exposing a photosensitive fibre to a periodic pattern of ultraviolet (UV) light. Their fundamental property is to reflect light over a narrow spectral range centered at a resonant wavelength known as the Bragg wavelength. Their ease of fabrication, combined with their unique properties, make them ideal for a great number of applications in telecommunication and sensing. A study of the Bragg grating properties is discussed in this paper. This study concentrates on the wavelength shift, reflectivity and bandwidth or FWHM of Bragg gratings.

## I. INTRODUCTION

Fibre optic Bragg gratings (FOBG's) have many applications in telecommunication and sensing [1]. These include its use in the construction of a fibre laser, as filters in fibre optic system, and as sensors for strain and temperature [2], just to quote a few examples. Before embarking on any work using FOBG, it is important to be aware of the various characteristics exhibited by such basic component. Here, we attempt to discuss this basic issues concerning some of the properties of FOBG and how they may be studied with minimum experimental setup.

## II. BASIC PROPERTIES AND SIMULATION RESULTS

The optical properties of the grating such as its peak reflected wavelength  $\lambda_p$  (the Bragg wavelength) and its reflectance  $\mathcal{R}$  will be determined by the fibre parameters as well as the grating parameters. The fibre parameters include the value of its effective core refractive index (RI)  $n_e$  and its profile, while the essential grating parameters are its period  $\Lambda$ , its length  $L$  and the amplitude of the index modulation  $m$ . A simple formula that relates the peak wavelength

$\lambda_p$  to the grating period  $\Lambda$  and the effective RI  $n_e$  is given by equation 1 [3]:

$$\lambda = 2 n \Lambda \quad (1)$$

Figure 1 shows the effect of varying the grating period on the peak wavelength. The results are obtained from a simulation study of the transmission characteristics using the IFO\_Gratings software [4]. The transmission characteristics for different grating periods are given in Appendix A.

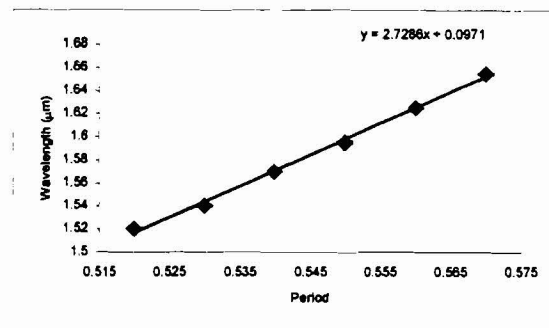


Fig. 1: Variation of peak wavelength with grating spacing

From the graph of Figure 1, the effective RI of the fibre core may be calculated from the slope and it gives a value of 1.36.

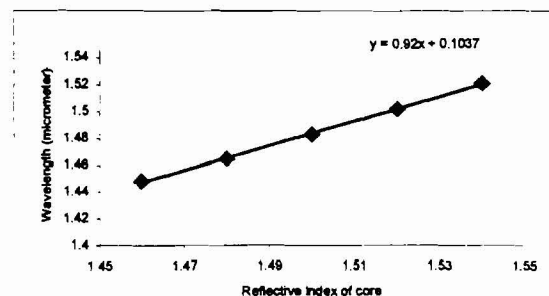


Figure 2 : Variation of peak wavelength for varying core RI

From equation 1, it will be obvious that the peak wavelength may also be varied by changing the effective RI of the fibre core. Results shown in Appendix B gives the graph in Figure 2, showing the variation in the peak wavelength for varying RI value of the core. It is also clear from the results of Appendix B that the width of the reflection spectrum reduces as the difference between the two RI's of the core and cladding increases.

By varying the index modulation amplitude of the grating  $m$ , the graph of Figure 3 shows an increase in the reflectance  $\mathcal{R}$  of the grating. The value of reflectance may be calculated from the transmission characteristic curve shown in Appendix C using equation 2:

$$\mathcal{R} = \left(1 - 10^{-\frac{R}{10}}\right) \times 100 \% \quad (2)$$

where R is the reflectivity in decibel.

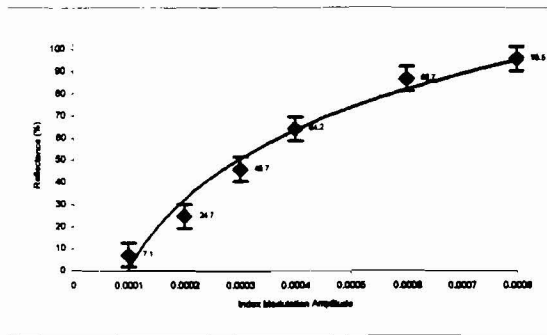


Figure 3: Variation of reflectance with index modulation amplitude

Appendix D shows the effect of varying the grating length and gives Table 1 which shows that the bandwidth (BW) of the grating increases with a decrease in grating length L. However, the result shows that the BW is not a linear function of L.

Table 1: Variation of grating bandwidth with grating length

No.	Grating Length, L ( $\mu\text{m}$ )	Grating bandwidth, BW (nm)
1.	1000	0.4
2.	900	0.8
3.	800	0.8
4.	700	1.2
5.	600	1.2
6.	500	1.2
7.	400	1.6
8.	300	2.4

### III. EXPERIMENTAL SETUP

A simple experimental setup may be used to observe the basic properties of the grating. Figure 4

shows the experimental setup used to determine the basic grating properties. The broadband source provides the light signal to be sent to the FOBG via port 2 of the circulator. The circulator ensures the light which get reflected from the FOBG will only leave the circulator via port 3 [5]. Another setup shown in Figure 5, with an isolator and a 3dB coupler replacing the circulator, may also be used, but with a less satisfactory result.

The reflected light from port 3 will be received by an optical spectrum analyzer (OSA) which will display the reflectance spectrum of the grating. Similarly, the transmission spectrum will be displayed by the OSA which is placed at the end of the circulator branch carrying the FOBG. Using this simple setup, the peak wavelength, the reflectance and the bandwidth (or FWHM) of the grating may be obtained.

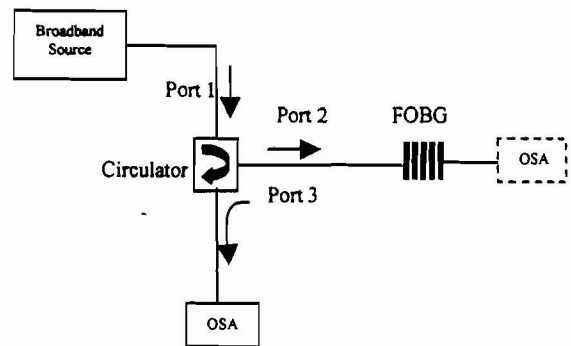


Figure 4: Experimental setup for measuring FOBG properties.

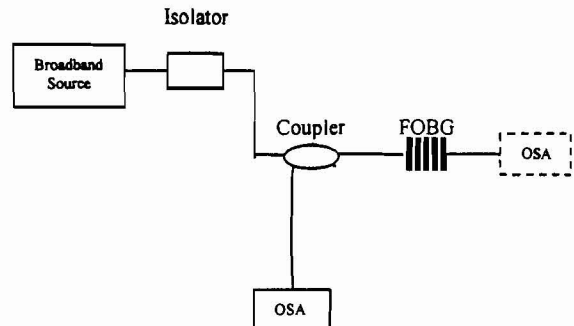


Figure 5: Measurement of FOBG properties using an isolator and a 3 dB coupler.

### IV. EXPERIMENTAL RESULTS AND ANALYSIS

Figure 6 shows a typical transmission curve obtained from the OSA data. The peak wavelength can be easily obtained from such result. All the FOBG tested give a peak wavelength of 1550 nm as that specified by the manufacturer.

From the transmission curve, the bandwidth or its FWHM may also be obtained. All the gratings tested give a value of bandwidth close to 0.1 nm.

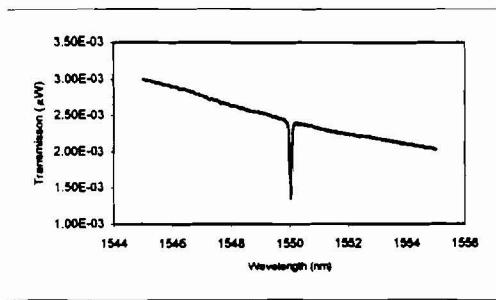


Figure 6: Transmission curve from optical spectrum analyzer data.

Figure 7 shows the actual display from the OSA, showing the reflection curve. The peak wavelength obtained from Figure 7 is 1550.070 nm.

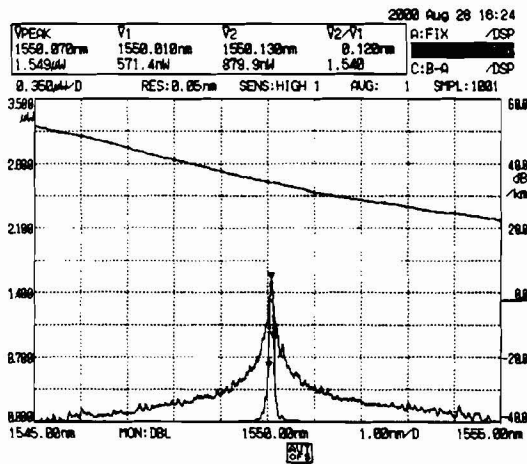
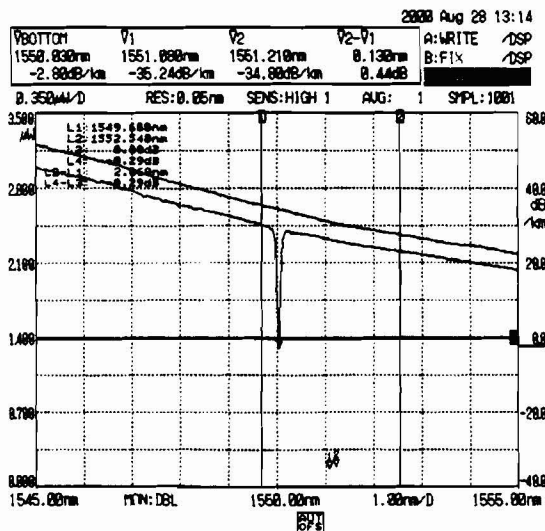
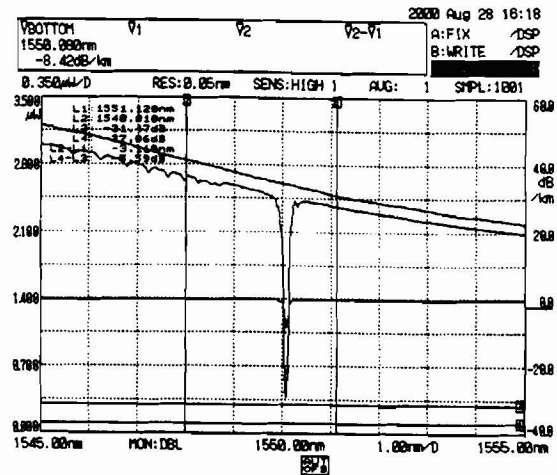


Figure 7: Reflection curve from the OSA display

The OSA display shown in Figure 8, which includes the transmission curve, may be used with equation 2 to give the reflectance of the grating.



(a)



(b)

Figure 8: The OSA display for grating with the propagation curve of the FOBG used (a) 48% reflectance and (b) 86% reflectance.

The reflectance obtained from Figure 8a is 48% whereas that from Figure 8b is 86%. These value are slightly lower than those estimated during the manufacturing process of the gratings.

## V. CONCLUSION

A simple experimental setup using a broadband source, a circulator and an OSA may be utilized to obtained the basic properties of a FOBG. Together with a simulation software, these properties may be studied and its variation with the fibre as well as the grating parameters, may be predicted.

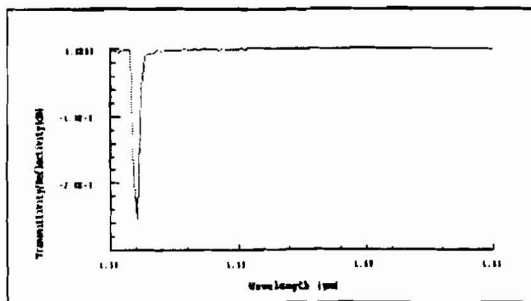
## VI. ACKNOWLEDGEMENT

We would like to thank Universiti Teknologi Malaysia for providing the grant, via IRPA, to undertake this project. To those involved directly or indirectly, please accept our sincere thanks and may Allah rewards us all.

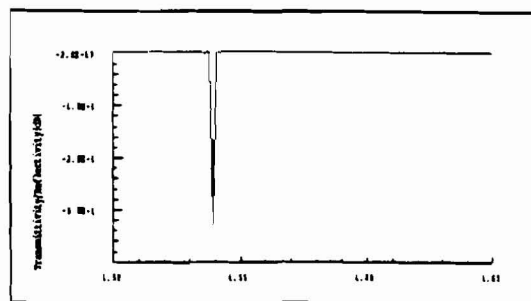
## REFERENCES

- [1] B. Culshaw and J. P. Dakin, "Revisiting Optical-Fiber Sensors", *Optical Fiber Sensors Volume Three*, pp. 1 – 8, 1996.
- [2] Jim R. Dunphy, Gerald Meltz and William. W. Morey, "Optical Fiber Bragg Grating Sensors: A candidate for Smart Structure Application", *Fiber Optic Smart Structures*, pp. 271 – 285, 1995.
- [3] Serge M. Melle, Kexing Liu and Raymond M. Measures, "Strain Sensing using a Fibre Optic Bragg Grating", *Fiber Optic Smart Structures and Skin IV*, SPIE Vol. 1588, pp. 255 – 263, 1991.
- [4] IFO\_Gratings, "Integrated & Fiber Optical Gratings Design Software", *Optiwave Corporation Manual*, 1997 – 1999.
- [5] P. St. J. Russell and J. L. Archambault, "Fiber Gratings", *Optical Fiber Sensors Volume Three*, pp. 9 – 67, 1996.

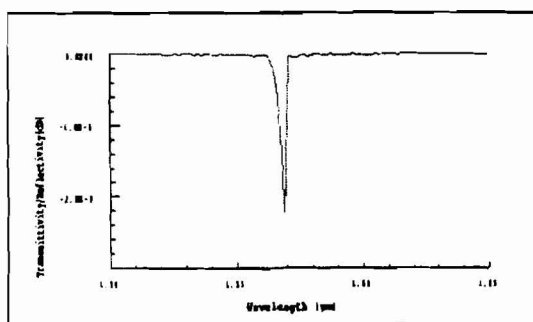
# APPENDIX A: Transmission curves for various gratings spacing.



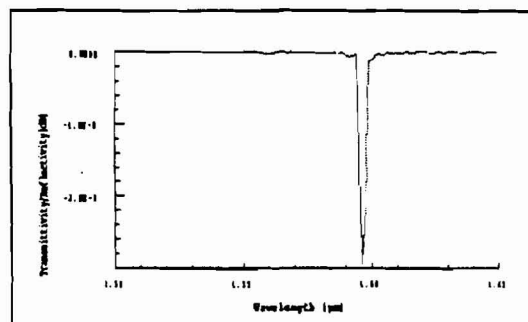
$\Lambda = 0.52\mu\text{m}$



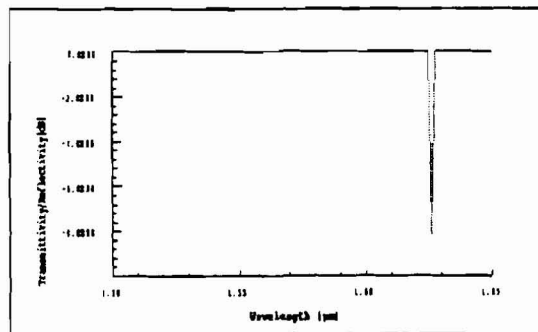
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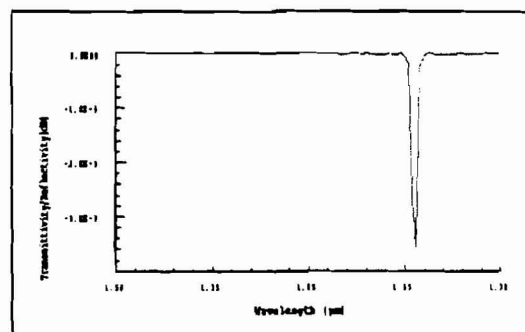
$\Lambda = 0.54\mu\text{m}$



$\Lambda = 0.55\mu\text{m}$

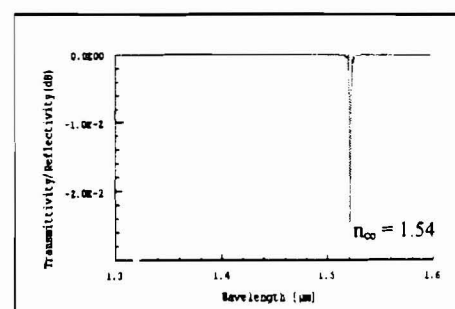
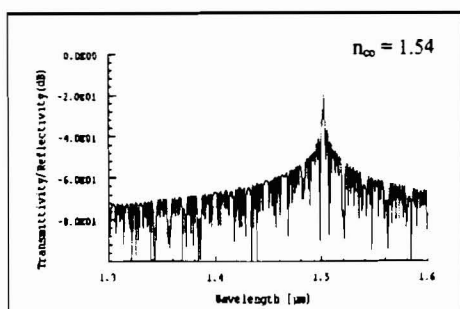
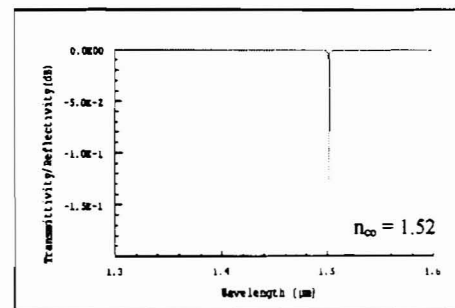
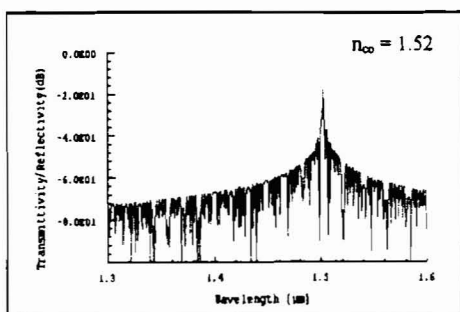
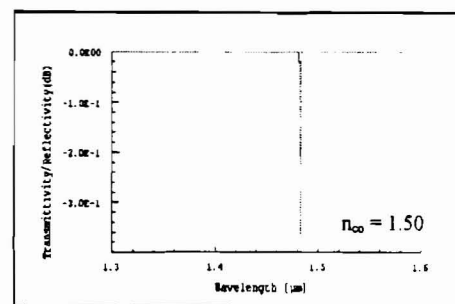
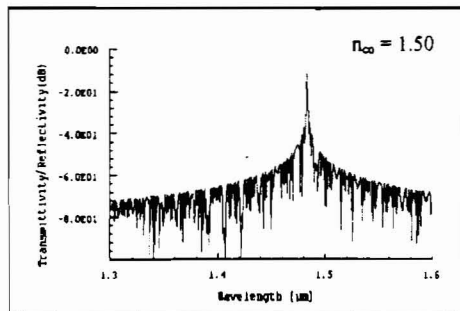
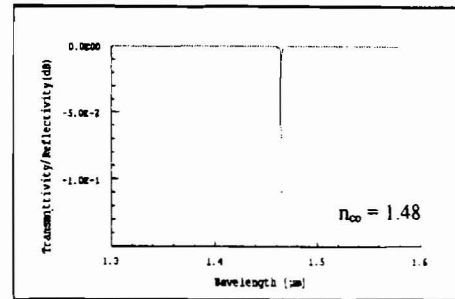
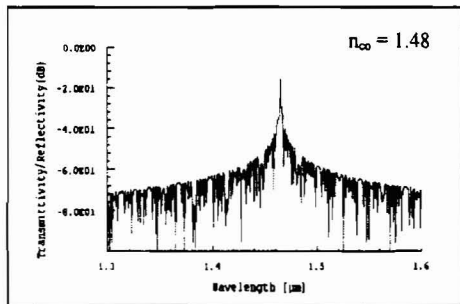
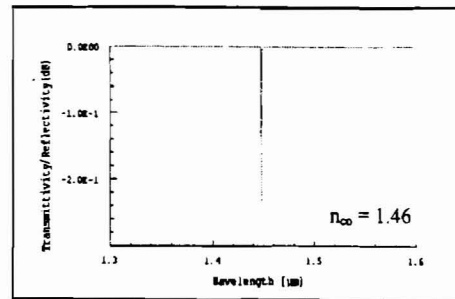
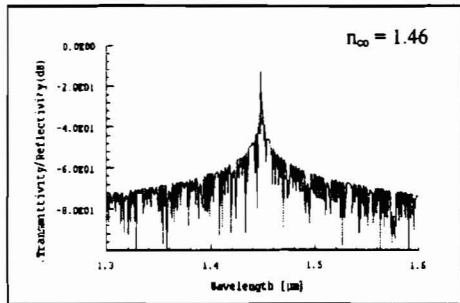


$\Lambda = 0.56\mu\text{m}$

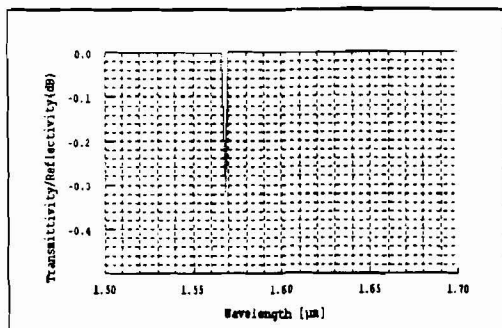


$\Lambda = 0.57\mu\text{m}$

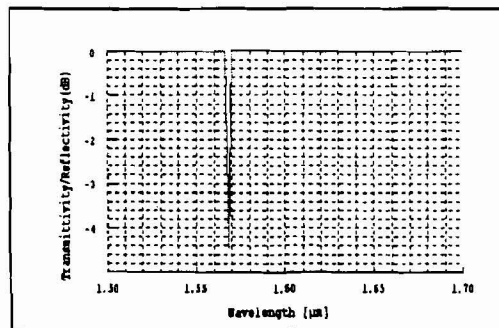
**APPENDIX B: Reflection and transmission spectra for various core RI ( $n_{co}$ ) with cladding RI of 1.44 and grating period of  $0.5\mu\text{m}$ .**



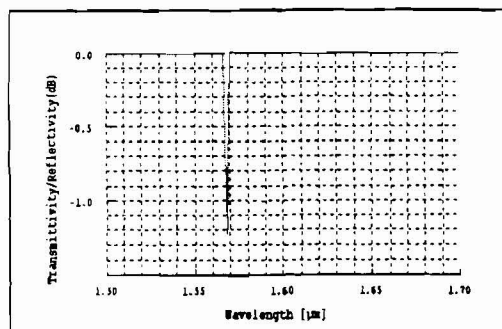
**APPENDIX C: Transmission cure of a 3mm grating with different index modulation amplitude (m), giving different values of reflectivity (R).**



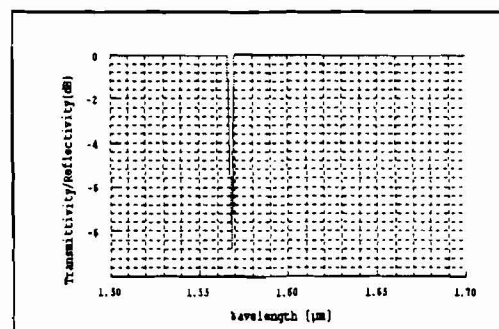
$m = 0.0001$ ,  $R = 0.32$  dB



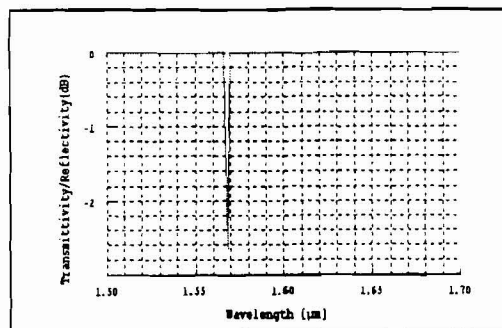
$m = 0.0004$ ,  $R = 4.46$  dB



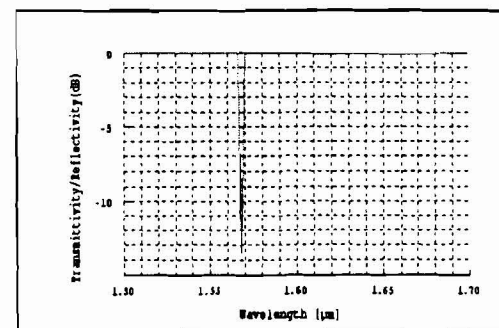
$m = 0.0002$ ,  $R = 1.23$  dB



$m = 0.0006$ ,  $R = 8.75$  dB

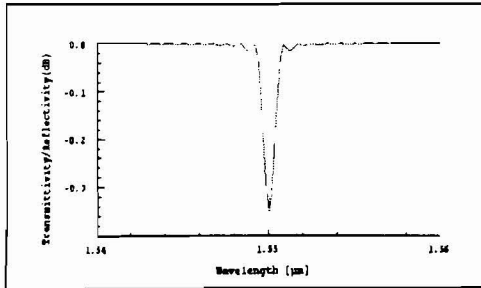


$m = 0.0003$ ,  $R = 2.66$  dB

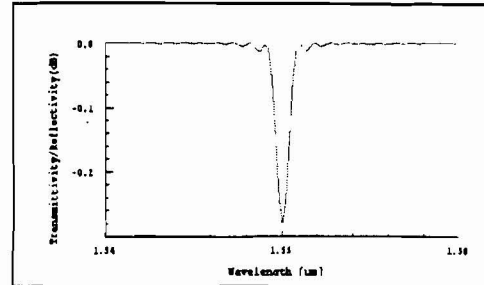


$m = 0.0008$ ,  $R = 13.48$  dB

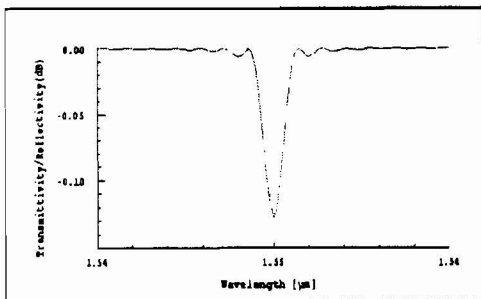
# APPENDIX D: Variation of grating bandwidth (BW) with grating length (L).



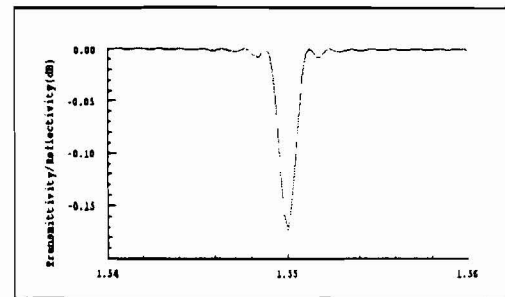
L = 1000  $\mu\text{m}$ , BW = 0.4 nm



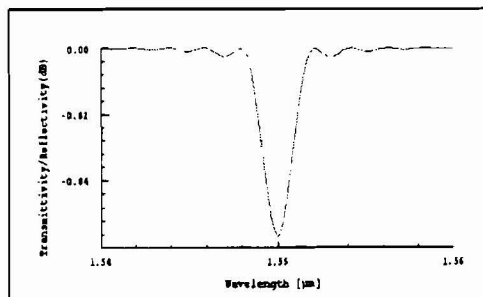
L = 900  $\mu\text{m}$ , BW = 0.8 nm



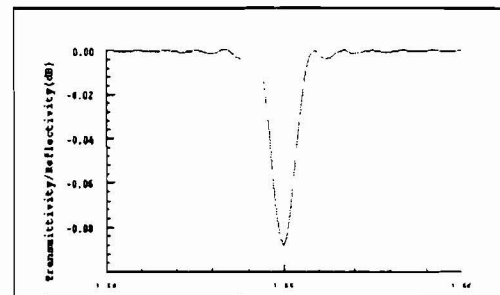
L = 800  $\mu\text{m}$ , BW = 0.8 nm



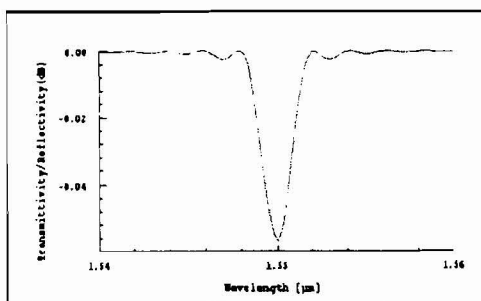
L = 700  $\mu\text{m}$ , BW = 1.2 nm



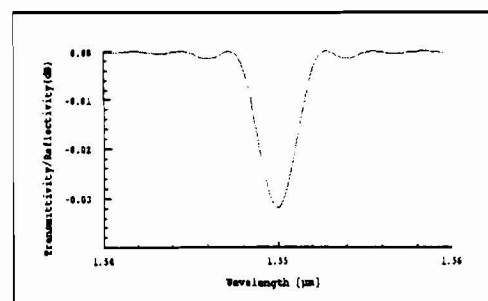
L = 600  $\mu\text{m}$ , BW = 1.2 nm



L = 500  $\mu\text{m}$ , BW = 1.2 nm



L = 400  $\mu\text{m}$ , BW = 1.6 nm



L = 300  $\mu\text{m}$ , BW = 2.4 nm